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ABSTRACT

This study was designed to extend the generality of the Substrata-Factor Theory by two methods of investigation: (1) theoretically, to establish the validity of the hypothesis that an isomorphic relationship exists between the Substrata-Factor Theory and the General Open Systems Theory, and (2) experimentally, to discover through a series of substrata analyses the patterns of interaction by which a set of subject matter areas mutually and reciprocally support each other. Eight postulates, fundamental to both the General Open Systems Theory and the Substrata-Factor Theory, were identified. It was concluded (1) that there was an isomorphic relationship between all postulates in the two theories; (2) that subject matter areas could be conceived of as suprasystems girded by diverse, yet fundamentally related, subsystems; (3) that working system hierarchies were found for each content area manifesting quantitative and qualitative differences in organization of substrata sequences, amount of variance called for, and redundancy of particular variables; (4) that reciprocal interaction could be inferred from and X on Y and Y on X regression analysis; and (5) that the proration sequential technique might provide a basis for determining the extent of a particular subsystem's impact on the suprasystem. Suggestions for further research and a bibliography are included. (This document previously announced as ED 024 546.) (JB)

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General Open Systems Theory and the Substrata-Factor Theory of Reading

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GENERAL OPEN SYSTEMS THEORY AND THE SUBSTRATA-FACTOR THEORY OF READING [1]

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Purpose

This study was designed to extend the generality of the Substrata-Factor Theory via two methods of investigation:

1. Theoretically, to establish the validity of the hypothesis that an isomorphic relationship exists between the Substrata-Factor Theory and General Open Systems Theory;

2. Experimentally, to discover through a series of substrata analyses the patterns of interaction by which a set of subject matter areas (reading, vocabulary, information, literature, grammar, numerical reasoning, arithmetic fundamentals, geography, history, and civics) mutually and reciprocally support each other. These patterns are used to illustrate the nature of the subsystems subsumed within a suprasystem as postulated in the theoretical models under consideration.

Method of Analysis

In Part I, a logical analysis of the postulates derived from the General Open Systems Theory and the Substrata-Factor Theory is made. Attention is particularly centered on the eighth postulate as an appropriate focus to illustrate in Part II the statistical application of the postulate.

In Part II, two substrata analyses are presented to discover the statistically significant contribution which each of the content areas makes to the other specified subsystems in an "idealized" mental cosmos which the model conceives as a syprasystem of interrelated working system hierarchies.

Part I

The integrating construct of this paper is General Open Systems Theory. General Open Systems theorists make

the following presumptions:

1. that inanimate and animate matter can be represented by systems,

2. that a greater unification among the various sciences is both desirable and attainable, and

3. that there exist general systems laws "which apply to any system of a certain type, irrespective of the particular properties of the systems or the elements involved" (Bertalanffy, 1950b, p. 138).

General Open Systems Theory has been described by Ashby (1958, p. 1) as symptomatic of a movement directing its attention to systems that are complex. Ashby notes that for the past two hundred years science has been interested primarily in whatever is simple, i.e., in identifying the units out of which complex structures are made. Thus Sherrington isolated the stretch reflex; Pavlov, the salivary conditioned reflex; Dodge, the corneal-reflection method for photographing eye movements. The rule was to fractionate and study one variable at a time.

Bertalanffy (1956, p. 2) indicates that one of the main problems of General Systems Theory is to deal with organized complexity. Logic would seem to demand not a special systems theory but a larger construct utilizing universal principles valid for "systems" in general in order to understand the characteristics of such organized complexity.

Bertalanffy defines a system as "sets of variables standing in interaction" (1956, p. 3).

Floyd Allport gives a comprehensive definition of a system:

> . . . any recognizably delimited aggregate of dynamic elements that are in some way interconnected and interdependent and that continue to operate together according to certain laws and in such a way as to produce a characteristic total effect. A system, in other words, is something that is concerned with some kind of activity and preserves a kind of integration

> and unity; and a particular system can be recognized as distinct from other systems to which, however, it may be dynamically related. Systems may be complex, they may be made up of interdependent sub-systems, each of which, though less autonomous than the entire aggregate is, nevertheless, fairly distinguishable in operation (1955, p. 469).

Astronomers have little difficulty defining a solar system, even though it is obvious that a particular solar system is part of a larger system such as a galaxy, which in turn is part of the Milky Way, which is embedded in the universe. The definition of a system is arbitrary and is highly dependent on a priori definitions of a task or problem:

> The concept of system, then, implies a goal or purpose, and it implies interaction and communication between components or parts . . . .
>
> A man-machine system is an organization whose components are men and machines, working together to achieve a common goal and tied together by a communication network (Gagne, 1962, pp. 15-16).

Systems may vary along two dimensions: (1) by their level of abstraction (pictorial, descriptive, or abstract mathematical); and (2) by the type of metaphor they employ (machine, organism, field, etc.) (Hearn, 1958, p. 40). The most appropriate metaphor for representing human individuals and human aggregates is the Organismic Open Systems Model.

From an analysis of dynamic and serviceable theories in a number of sciences including biology, chemistry, and physics, Bertalanffy (1945, 1950a & b, 1956) identified or abstracted seven attributes of an Organismic Open Systems Model; Werner (1948), an eighth:

1. Open Systems exchange energy and information with their environment through input and output channels.

2. Open Systems tend to be characterized by steady states as those of organic metabolism - a constant ratio being maintained by the components of the system. An inanimate example is that of a candle.

When first lighted it's flame is small, but grows rapidly to its normal size and maintains this size as long as the environment of the flame remains constant.

3. Open Systems manifest regulating tendencies of the organism to reestablish a steady state after being disturbed. A sudden draft will cause a flame to flicker, but the flame quickly regains its normal characteristics once the ventilation of the room has been restored.

4. Open Systems exhibit equifinality - a final state may be reached from different conditions and/or different ways. Hearn illustrates the concept of equifinality by the case of two babies born at the same time, one of whom is premature, the other full term:

> While at birth they will have been different in appearance and stage of development, within a very few weeks after birth they will probably have achieved a similar stage of development. What this seems to mean is that for every species there is a typical or characteristic state; indeed, for every individual within the species there is a characteristic state which he, by nature, must strive to assume. It is perhaps more accurate to say he has characteristic states for each successive stage of development (1958, p. 45).

Consistent with the postulate of equifinality is that different initial conditions may lead to an equivalent characteristic state.

5. Open Systems display a dynamic interplay of subsystems operating as a fruitful process which is in part responsible for the maintenance of a steady state. A change of some quantity is a function of the quantities of all elements. "The system, therefore, behaves as a whole, the changes in every element depending on all others" (Bertalanffy, 1950b, p. 146).

6. Open Systems evince feedback processes, wherein the output is compared against desired performance and past behavior, which contribute to the maintenance of the steady state.

7. Open Systems display progressive segregation - a process wherein systems divide into a hierarchical order of subordinate systems. It has been assumed that the process of segregation is related to negative entropy wherein the organism progresses to higher levels of order and differentiation. Disorganization (positive entropy) and organization (negative entropy) operate in a living organism during the entire course of life.

> In the early stages of life, organization outruns de-organization, so that the organism becomes more and more differentiated or, in other words, grows. With adulthood, life continues, but growth slows to a stop. With old age de-organization outruns organization, and with death organination terminates and de-organization, resulting from the free play of entropy, has full reign (Bray and White, 1954, p. 75).

8. Open Systems also display progressive integration. Higher order systems are continually being formed from the organization of smaller systems into functional hierarchies united to cope with problems of greater complexity than can be handled by any of the subordinate systems alone. This is a function of negative entropy.

Concurrent and independent of Bertalanffy[2] (1945: 1949 (trans. to English, 1952), 1950a & b, 1951, 1955, 1956, 1962a & b) and other open system theorists who have published in The Society for the Advancement of General Systems Theory since 1956, and the Journal of Behavioral Science also founded in 1956, Holmes (1948, 1953, 1954, 1960, 1961a & b, 1963a & b, 1964a) and Holmes and Singer (1961, 1964, 1965) developed the Substrata-Factor Theory of Reading.

The major hypothesis of the analysis to be described in this paper is that the Substrata-Factor Theory of Reading and Open Systems Theory are isomorphic to each other, i.e., are structurally similar.

Brodbeck points out that isomorphism requires two conditions:

1. There must be a one-to-one correspondence between the elements of the model and the

elements of the thing for which it is a model. For every chimney stack, there is a miniature chimney. Every window has its replica and vice versa.

2. Certain relations are preserved. For instance, if a door is to the left of a window in the original, their replicas are similarly situated; the model is constructed to scale. The model may or may not "work" on the same principle as the original. If it does, the isomorphism is complete. If for instance, a model of a steam engine is also steam propelled, then the isomorphism is complete (Brodbeck, 1959, p. 374).

The breadth of the Substrata-Factor Theory is indicated by Holmes in the following summary which defines reading in terms of his theory:

> In essence, the Substrata-Factor Theory holds that normally reading is an audio-visual verbal processing skill of symbolic reasoning, sustained by the interfacilitation of an intricate hierarchy of substrata factors that have been mobilized as a psychological working system and pressed into service in accordance with the purpose of the reader (1960, p. 115).

Significance of Analysis

The significance of the following analysis rests in its attempt to show that the essential <u>form</u> of the postulates of the Substrata-Factor Theory are identical with the generalized <u>form</u> of the fundamental postulates that have been discovered to hold for modern theories in other sciences. If this can be done, it will show that the postulates of the Substrata-Factor Theory which were formulated to explain the <u>content</u> of a specific discipline, reading, without regard to form, nevertheless, fit the formal criteria of the General Open Systems Models as abstrated from other sciences. What would this prove? Most importantly, it would show that the formal aspects of the Substrata-Factor Theory were not only consistent with similar Open Systems theories in other sciences, but

also that it was internally consistent. The presentation that follows is an attempt to show how the Substrata-Factor Theory parallels General Open Systems Theory.

In this paper, each of the General Open Systems Theory postulates is stated. After each general postulate a discussion relates the Substrata-Factor Theory in that area to the General Open Systems Theory.

General Open Systems Theory Postulate I: Exchange of energy, information, or matter with the environment through input and output channels. Interaction between the individual and the environment implies that the total variance of any response can be accounted for only in part by individual differences. It depends also on the stimulus characteristics of the environment and the interaction between the individual and his milieu.

The total range of "outside" and "inside" variables has an impact on the output of the individual's achievement. S. B. Sells (1963, pp. 9-13) has outlined some two hundred manageable variables that can be empirically measured. Sells' effort is a first step toward the development of taxonomic dimensions to account for the total stimulus situation.

The five major headings around which these two hundred variables are grouped include natural aspects of the environment; man-made aspects of the environment; description of task-problem, situation and setting; external reference characteristics of the individual; and individuals performing in relation to others.

The Substrata-Factor Theory predicts that a child s achievement hierarchy, which would include many variables in each of the above five major headings, will undergo a gradient shift or orderly change as he progresses through school. As the individual increases his proficiency in newly learned subskills, the content and structuralorganization of the substrata factors in the hierarchy which underlie his developing ability to achieve will also change.

General Open Systems Theory Postulate II: Maintenance of steady states. The concept of a steady state was probably first stated by Mareau de Maupertuis (1698-1759) in his Essai de Cosmologie (1750) in which he described the principle of least action. In biological terms Claude Bernard (1865) expressed Maupertuis' principle as the maintenance of the internal environment. Fechner (1873),

in a practically unknown monograph, describes his idea of the steady state as follows:

> All development progresses in the direction of an always more complete utilization of energy for stationary systems - maximum stability, therefore, always means maximum utilization of energy (quoted in Menninger, Mayman, & Pruyser, 1963, p. 82).

Cannon conceived of homeostasis, wherein a physiochemical constancy is maintained, such as the automatic regulation of body temperature, the pH level of the blood, and the maintenance of osmotic pressure.

In the field of reading, the Substrata-Factor Theory postulates a working system of subabilities which are directed toward the solution of a problem.

> . . . . The problem organizes the abilities, as the abilities determine what may be organized. That is, the particular kind of problem requires a certain organization of abilities, as the individual possession of certain abilities limits what he may organize (Holmes, 1953, Ch. 32, pp. 1-2).

Neurologically, a working system is conceived of by Holmes (1960, p. 117) as a nerve-net pattern in the brain that functionally links together the various subsystems that have been mobilized in a workable communications supersystem. A first approximation of how this working system might be determined is at present statistically derived by a Wherry-Doolittle-Holmes Substrata Analysis.

On the basis of Holmes' extension of the steady-state principle to reading, the Substrata-Factor Theory predicts that working systems would vary with the problem, the purpose, and the stage of psychoeducational neurological development of the individual.

General Open Systems Theory Postulate III: <u>Self-regulating tendency--reestablish a steady state after being disturbed</u>.

> . . . . The very counteractivity which corrects the undesirable deviation often proceeds in an oscillating fashion. Restoration of the original state of equilibrium

> is not a very smooth process, but consists of a series of pulls and pushes, like the swings of a pendulum, which gradually approximates the center-of-gravity position. The corrective activity may overdo or underdo the job it is called to do; there may be an overshooting or undershooting of the mark while the corrective process is going on (Menninger, Mayman, & Pruyser, 1963, pp. 87-88).

In terms of reading, the deviation of a working system from its steady state may be manifest in the return sweep, number, and pattern of fixations, regressions, and the duration of fixation. For instance, regressions have been studied most intensively by Bayle (1942), who noted that causes of regressions may be found in the type of material and the difficulties the reader experiences in deriving meaning. Six interpretation difficulties which affect the eye-movement patterns were identified by Bayle as word order; word grouping; misleading juxtaposition of certain words; lack of punctuation to make the meaning clear; shifts in the meaning of words; and the necessity for concentrating on key words or key elements in sentence units.

The Substrata-Factor Theory holds that when the working system is inappropriate for the reader's purpose (specific word attack in an otherwise easy passage), the steady state will be disturbed, and the working system will make internal adjustments in an effort to solve the problem. Upon clarification, the original working system will be restored.

Several interesting questions are raised by Menninger, Mayman, and Pruyser (1963) about the concept of self-regulation and return to the steady state.

> Is there a complete return to the status quo ante?
> Is the process of disequilibriation to equilibriation a circular one?
> Are the mechanics of control the same at every level?
> Does it equally apply to parts and wholes, to systems, subsystems, and supersystems?
> Is there growth of self-regulating action and decline of it?

Most of the answers to these questions would involve carefully executed microscopic and macroscopic studies, but the Substrata-Factor Theory would predict, as far as reading is concerned, a qualified negative answer to the first four.

General Open Systems Theory Postulate IV: Equifinality. Bertalanffy has pointed out that equifinality in Open System Models is another of the characteristics which distinguish them from closed systems:

> In closed systems the final state is unequivocally determined by the initial conditions: for example, the motion of a planetary system where the position of the planets at a time t are unequivocally determined by their position at a time t_o. Or in a chemical equilibrium, the final concentrations of the reactants naturally depend on the initial concentrations. If either the initial conditions or the process is altered, the final state will also be changed. This is not so in open systems. Here the same final state may be reached from different initial conditions and in different ways. This is what is called equifinality, and it has significant meaning for the phenomena of biological regulation . . . . The sea urchin can develop from a complete ovum, from each half of a divided ovum, or from a fusion product of two whole ova. The sample applies to embryos of many other species, including man, where identical twins are the product of the splitting of one ovum (1955, p. 77).

The Substrata-Factor Theory states that different individuals (or the same individual at different times) may perform the same task to an equal degree of success by drawing upon different sets of abilities. This hypothesis was substantiated for power of reading based on a comparative substrata analysis of the working systems of boys and girls at the high school level (Holmes & Singer, 1961).

General Open Systems Theory Postulate V: Dynamic interplay of the subsystems. The dynamic interplay of subsystems is well described by Menninger, Mayman, and Pruyser (1963):

> A hierarchy of levels can be recognized, each with its own mode and means of homeostatic regulation, interrelated by an over-all homeostatic tendency (p. 65).

Five specific interactions of the various subsystems are indicated by Luby (1962): a receptor system for external stimuli; a receptor system for internal stimuli including those from muscles, joints, and viscera; a system for filtering the diverse sensory input and integrating and interpreting it; an effector system involving autonomic and volitional motor acts; a chemical energy production system necessary for the adequate evocation of reactions in each of the separate systems mentioned.

The Substrata-Factor Theory postulates that the various substrata factors are tied together in a working system; and as their interfacilitation in the working system increases, the efficiency of the child's reading also improves. Such diverse substrata factors initially become associated in a particular working system by the psycho-catalytic action of mobilizers--hypothetical constructs which are deep-seated value systems (Holmes, 1959).

General Open Systems Theory Postulate VI: Feedback process. The feedback concept has been highlighted by cybernetics in terms of servomechanisms, i.e., some device that controls some variable in a special way by comparing its actual value with a desired reference value.

Recently, Fender (1964), a professor of biology and electrical engineering, has described the human body as a collection of servomechanisms. Feedback critical systems regulate such functions as body temperature, constitution of body fluids, the flow of blood to the organs and extremities, and the rate of breathing to the level of physical activity.

Fender did an intensive microscopic analysis of the control mechanism of the eye and found that the microscopic structure of the retina is similar to that of the brain. In fact, he notes, the retina is part of the brain that became detached in the course of evolution (1964, p. 32).

The implication of Fender's systems analyses of the eye enhances the idea that the retina contains not only light-sensitive rods and cones but also bipolar cells.

amacrine cells, and ganglia which may equip it to process some information in its own right. The eyes are not merely a reflector of higher mental process or a mechanical camera. (See also Granit, 1955.)

The Substrata-Factor Theory postulates a continuous monitoring of the meaningful material in order for mobilizers to effect the successive compensations necessary within the working systems as they fluctuate around their hypothetical steady states.

General Open Systems Theory Postulate VII: Progressive segregation and hierarchical order of subsystems. This postulate is very similar to the organismic-holistic orientation of Werner and Kaplan who assume". . . that organisms are naturally directed towards a series of transformations--reflecting a tendency to move from a state of relative globality and undifferentiatedness towards states of increasing differentiation and hierarchic integration" (1963, p. 7).

Further, Werner and Kaplan maintain that, with the attainment of higher levels, lower-level functions are not lost but under normal circumstances subordinated to more advanced levels of functioning. Under special conditions, such as dream states, pathological states, intoxication, drugged states, various experimental conditions or confrontation with especially difficult and novel tasks a partial return to more primitive modes of functioning before progressing towards higher-level operations may be evidenced. This tendency has been described by Werner (1948) as the genetic principle of spirality.

The Substrata-Factor Theory postulates the gradient shift in perceptual-conceptual differentiation within and between kinesthetic-auditory and visual modes of learning. There is continual interaction between the whole and its parts. As the parts become more differentiated and meaningful, so does the whole; and as the whole becomes more meaningful, so do its parts (Holmes, 1953, Ch. 32, p. 7).

What constitutes part and whole is a perennial scientific problem continually being analyzed by the nature of scientific reduction. In any scientific observation what is taken as the whole and what as the parts? The history of science indicates that the answers to this question are inextricably bound up with the personal preference of the experimentalist, his concepts of causality, the culture he belongs to, the Zeitgeist of the

times he lives in, and the nature of the material or experiment.

General Open Systems Theory Postulate VIII: Progressive integration. Postulate VIII develops from Postulate VII; with the continued organization of smaller subsystems into functional hierarchies, a more integrative supersystem also emerges.

Each of the constituent subprocesses must be thought of as integral parts of the whole that work together and contribute proportionately to its total in each and every situation in which the supersystem works.

> By additive processes, series-combinations of suitable systems, interlaced with parallel-combinations as desired, may be constructed into larger and larger systems. Thus, hierarchies of subsystems may be developed: subsystem of subsystem of subsystem, etc. (Ellis & Ludwig, 1962, p. 11).

Miller, Galanter, and Pribram come to grips with the supersystem subsystem relationships as follows:

> The implication is relatively clear, however, that the molar units must be composed of molecular units, which we take to mean that a proper description of behavior must be made on all levels simultaneously. That is to say, we are trying to describe a process that is organized on several different levels, and the pattern of units at one level can be indicated only by giving the units at the next higher, or more molar, level of description.
>
> For example, the molar pattern of behavior X consists of two parts, A and B in that order. Thus, X = AB. But A, in turn, consists of two parts, a and b; and B consists of three, c, d, and e. Thus X = AB = abcde, and we can describe the same segment of behavior at any one of the three levels. The point, however, is that we do not want to pick one level and argue that it is somehow better than the others; the complete description must include all levels. Otherwise, the comparative properties of the behavior

> will be lost--if we state only abcde, for example, the (ab) (cde) may become confused with (abc) (de), which may be a very different thing.
>
> This kind of organization of behavior is most obvious, no doubt, in human verbal behavior. The individual phenomena are organized into morphemes; morphemes are strung together to form phrases; phrases in the proper sequence form a sentence, and a string of sentences makes up an utterance. The complete description of the utterance involves all these levels. The kind of ambiguity that results when all levels are not known is suggested by the sentence, "They are flying planes." The sequence of phonemes may remain unchanged, but the two analyses (They) (are flying) (planes) and (They) (are) (flying planes) are very different utterances (1960, pp. 13-14).

Holmes utilizes the concept of substrata factors which is a dynamic set of subsystems continually being organized and reorganized in the brain depending on the task confronting the organism. Neurologically, substrata factors are

> . . . neurological subsystems of brain cell-assemblies, containing various kinds of information such as memories for shapes, sounds, and meanings of words and word parts, as well as memories for vicarious and experiential material, conceptualizations, and meaningful relationships stored as substantive verbal units in phrases, idioms, sentences, etc. Such neurological subsystems of brain cell-assemblies gain an interfacilitation, in Hebb's sense (Hebb, D.O. The Organization of Behavior. New York: John Wiley & Sons, 1949, p. 335), by firing in phase. By this means, appropriate, but diverse subsets of information, learned under different circumstances at different times and, therefore, stored in different parts of the brain are brought simultaneously into awareness

> when triggered by appropriate symbols on the printed page. These substrata factors are tied together in a working-system, and as their interfacilitation in the working-system increases, the efficiency of the child's reading also increases (1960, p. 116).

Related to the hierarchy of subsystems upon which General Open Systems Theory and Substrata-Factor Theory depend is the assumption of multicausality or reciprocal causation.

McEwen (1963, p. 337) refers to reciprocal causation as the reversibility of cause-effect relations. Physical events are relatively free from reciprocal influence; but biological and sociocultural situations often mutually determine each other.

MacIver notes that "one can reverse with some degree of truth almost any statement of social causation." He illustrates this as follows:

> Does the kind of education account for the standard of intelligence in a community? True, but does not the standard of intelligence account for the standard of education? (1942, p. 68).

Neurath (1938) called this postulate 'reciprocity-mutual causation' and abandoned it because it makes sociocultural data too "clumsy and perplexing."

In contrast to such a conception of multiple causation, there are the monocausal models of Watson's conditioned reflex or Freud's sexual compulsion and Marx' economic determinism. As Feigl has sagaciously noted:

> . . . in most of the significant applications we must remember that it is an entire set of conditions that represents "the cause of an event" and that what we may abstract as "cause" or "effect" in a complex situation is usually only some factor, aspect, magnitude, etc., that we select from a more complex (and possibly inexhaustible) welter of factual details (1953, p. 410).

Hook (1937) calls for a "functional theory of causation together with all the apparatus of statistical inquiry" and for "developing a theory of measurement to determine the relative weight of various causal factors considered." Only a multicausal theory could "offer an explanation of the correlations found."

The substrata factor analysis which is the statistical model supporting the Substrata-Factor Theory accepts the reciprocal causation postulate. Statistically, a substrata analysis consists of Holmes' extension of the Wherry-Doolittle Multiple Selection Technique. The W-D-H substrata analysis

(a) yields successive sets of subvariables,

(b) gives each set a definite place in a complex hierarchy of subabilities, and

(c) discovers statistically significant contributions which each of the subabilities in the hierarchy makes to the criteria immediately above it in the over-all hierarchy of skills and also to the major criterion itself.

Figure 1 shows the generalized schema of a substrata analysis. The studies to date, however, take into consideration only the X on Y regression. Hence, while the Substrata-Factor Theory postulates reciprocal causation and makes provisions for such analyses in the design of the 7094 digital computer program for a substrata analysis, the actual analyses, to date, have been in only one direction. Since cause and effect cannot be directly inferred from either simple or multiple correlation, the postulate of reciprocal cause and effect cannot be either substantiated or refuted on the basis of a statistical substrata analysis.

On the other hand, all knowledge possessed by a normal individual and all mental processes within the same individual must be actively associated or at least may become associated by an existing mental mechanism in the brain. The actual degree to which they are associated on the average may be expressed by the coefficient of correlations. While correlations cannot in any way substantiate reciprocal cause and effect relationships, the correlational analysis can and does give an estimate

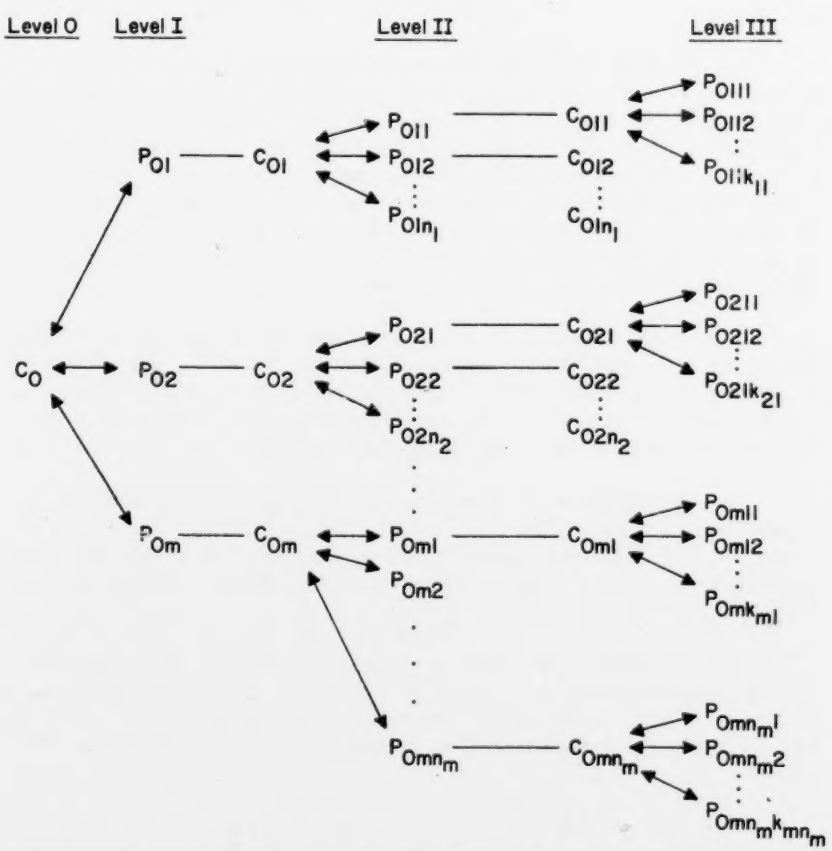

Fig. 1. Schematic Diagram with generalized notation of a substrata analysis through three levels.

Major criterion C_0 is undergirded by substrata factors $P_{01}, P_{02}, \ldots P_{0m}$. Each of these rest on a wider base at Level II. Likewise, at Level III the base is even broader. $P_{0m} \text{---} C_{0m}$ terminology is used to indicate an identity, except that what was considered a predictor is in turn considered a subcriterion.

From: Holmes, J. A., & Singer, H. The substrata-factor theory: substrata factor differences underlying reading ability in known-groups at the high school level. U.S. Office of Education Contracts 538, SAE-8176 and 538A, SAE-8660, 1961, 59.

of the reciprocal interactions that may be going on among the variables.

In addition to hierarchical organization of sub-systems' reciprocal causation is a need to reformulate the dependent-independent variable nexus. The dependent variable is (a) the response or criterion; and/or (b) the symbol whose values are determined by the other variables linked with it in an algebraic equation. The independent variable is (a) any variable which is not the criterion variable; and/or (b) the variable which is not dependent upon changes in any other variable.

However, in educational psychology there is no such thing as an absolutely independent variable. The "independent" variables usually identified with environmental conditions or personal characteristics are reciprocally dependent and often statistically related.

The fundamental relation of all variables may be expressed in the form $Y = f(X)$, which reads "Y is a function of X", and means that Y changes in a way to be discovered and/or stated whenever X changes (English & English, 1958, p. 578).

The question of when a variable should be regarded as an independent or "causal" variable and when as the dependent or "resultant" variable is, in the final analysis, left to the judgment of the experimenter. (Ezekiel & Fox, 1959).

The choice of the metaphors used by General Open Systems Theory and the Substrata-Factor Theory for this investigation has been guided by the following characteristics of human beings which Hearn (1958) outlined so well:

1. Humans exchange material with their environment, in the form of both energy and information.

2. This energy may arise either from within the system or from the environment of the system.

3. Human behavior is purposive.

4. When considered both as individuals and as species, humans have a characteristic state toward which they move.

5. Humans may achieve their same characteristic state from different initial conditions and from varying inputs of energy and information.

6. In the human individual as well as in human aggregations such as groups and communities, there is a dynamic interplay among their essential functional processes enabling them to maintain a steady state.

7. There is a tendency in human systems toward progressive mechanization; that is, in the course of human development, certain human processes tend to operate more and more as fixed arrangements.

8. Human systems show a resistance to any disruption of their steady state.

9. They are capable, within limits, of adjusting to internal and external changes.

10. They can regenerate damaged parts.

11. They can reproduce their own kind.

Part II

The empirical aspects of this study are related to a systems analysis as defined by Peach (1960) and Ryans (1964):

> By systems study or systems analysis will be meant observation directed at the determination of relevant elements of a system and their operations and interactions as they contribute to the relative efficiency with which the system outcome is produced. It will be necessary to identify and analyze properties and subsystems in order to determine chains of influence which contribute to activities and elements, and it will be necessary to put these pieces together and to synthesize the information to describe the larger systems in which our interests may be focused (Ryans, 1964, p. 23).

Specifically, Part II is concerned with determining the answers to this problem: When each of the content areas are in turn used as criterion tasks, how do the remaining content area subsystems relate to the particular subject matter under consideration? To what degree does each of the content areas co-vary with the rest of the independent variables?

It is hypothesized that working system hierarchies for each of the content areas will manifest quantitative and qualitative differences in the organization sequences as well as magnitudes of the various subsystems.

The Substrata Analysis Method

The statistical method used to infer working-systems is a substrata analysis, an extended form of the Wherry-Doolittle Multiple Test Selection Technique. Wherry (1931, 1940a & b, 1947) and Stead and Shartle (1940) modified the Doolittle least squares technique (1878) so that the variables selected would be only those which were most independent of those already chosen and would, therefore, tend to make a maximum contribution to the multiple prediction of a criterion. The selection process stops when more chance error than predictive variance would have been contributed by the selection of another predictor.

Holmes' (1948) extension, the substrata analysis, repeats the Wherry-Doolittle procedures using each predictor as a subcriterion. The preferential predictor selected at each level becomes in turn a subcriterion at a subsequent level to be analyzed by predictors selected from the remainder of the correlation matrix. Reiteration at present extends to three levels.

Consistent with the second major purpose of the study which forms the basis of this paper, nine substrata analyses took each content area as a criterion in order to determine what proportion of intraindividual variance is accounted for by the remaining content area subsystems. Two of the nine areas analyzed, Power of Reading and Vocabulary in Isolation, are presented here.

Table 1

Intercorrelations, Means, and Standard Deviations of Content Areas for Subsystem Interaction Analysis (N = 120)[a]

No. Variables[b]	1	2	3	4	5	6	7	8	9	Index of reliab[c]
1 Power of Rdg.	——	.823	.693	.718	.576	.695	.663	.486	.548	.93
2 Vocab. in Isol.			.734	.795	.713	.664	.679	.387	.499	.95
3 General Info.[d]				.720	.587	.721	.697	.357	.501	.87
4 English Lit.					.565	.691	.649	.312	.465	.90
5 Grammar						.511	.528	.280	.371	.90
6 Geography							.769	.296	.441	.93
7 History-Civics								.311	.450	.84
8 Arith. Rsng.									.586	.91
9 Arith. Fund'ls									——	.95
Mean	101.01	99.72	13.28	95.49	95.37	89.34	85.65	91.97	90.99	
Std. Dev.	11.59	11.89	4.07	13.15	16.50	19.74	15.32	12.35	19.32	

[a]Correlations must be .24 to be significant at the 1% level of confidence.

[b]Based on Stanford Achievement Tests administered in Adolescent Growth Study as part of longitudinal analyses at Institute of Human Development, University of California, Berkeley. See: Jones, 1938, 1939a & b, 1958. Tests renamed for theoretical consistency.

[c]The index of reliability gives the maximum correlation possible between the obtained scores and their theoretically true scores. See: Garrett, 1958, p. 349.

[d]A subtest from the Terman Group Test of Mental Ability.

Working System Hierarchy of Power of Reading

An examination of the correlation matrix in Table 1 reveals that Vocabulary in Isolation has the highest zero-order correlation with the criterion Power of Reading ($r = .823$). Therefore, Vocabulary in Isolation will be selected as the first predictor test by the Wherry-Doolittle Test Selection Method. Since r^2 in this instance equals .6773, Vocabulary in Isolation cannot account for more than 67.73 per cent of the criterion's variance. However, 67.73 per cent needs to be corrected in terms of the other predictors which the method selects as well as the bias which arises from chance factors characteristic of sampling and selection techniques.

Specifically, when the contributions of all the selected predictors to criterion variance are computed, Vocabulary in Isolation will account for less of that variance than the value of r^2. This is due to the calculation of the beta weights for this particular predictor in addition to the other variables which make independent contributions to the variance of the criterion. These variables will take from the Vocabulary in Isolation subsystem some of the variance which this "most valid" predictor appears to have contributed to the Power of Reading criterion by being selected as the first test. In terms of the Substrata-Factor Theory the ". . . immediate problem is to discover which of the other variables in the matrix will be selected along with (Vocabulary in Isolation) as those variables at Level I which can be thought as having a direct and joint influence" (Holmes and Singer, 1961, p. 81) in the variation of ninth grade students' scores in Power of Reading. After Level I predictors have been selected, the next step is to use these predictors as subcriteria and determine what preferential predictors underlie these at Level II.

A pictorial display of the interaction among the various subject-matter subsystems in the working system of Power of Reading is presented in Figure 2. The major criterion, Power of Reading, is placed on the left under Level 0. Arrayed from left to right are the subject-matter subsystems selected by the substrata analysis. The path of the regression relationships between subsystems is indicated by unidirectional arrows. Mutual interaction representing interaction equally assigned in both directions is shown by double-ended arrows. The numbers adjacent to the unidirectional and bidirectional arrows

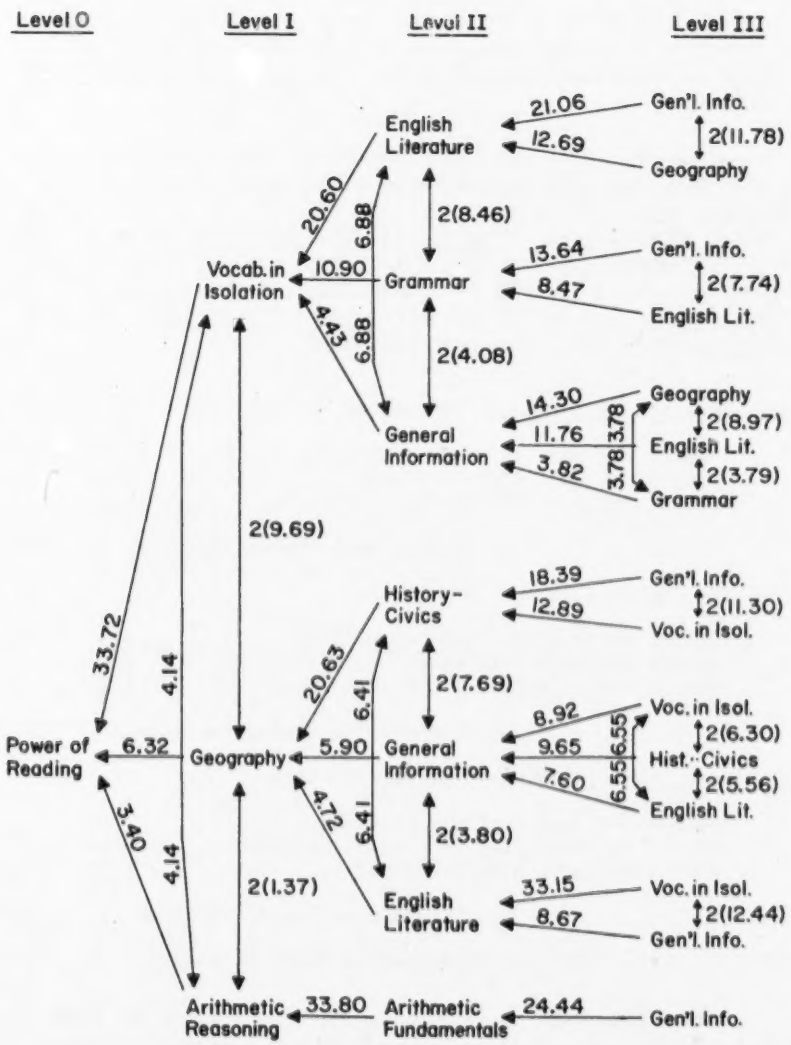

Fig. 2. Schema showing interaction among subject matter subsystems in the working system of Power of Reading; figures represent adjusted proportional variance as per cent.

indicate the relative strength of the interaction accounted for by each subject matter subsystem.

The content area subsystem, the substrata sequence, and the per-cent contribution to variance in Power of Reading at the ninth-grade level can be read from Fig. 2 as follows:

Beginning with Power of Reading, the major criterion, one can see that three subsystems precipitated from the substrata analysis to account for 73.84% of the variance in Power of Reading. The total contribution (direct plus shared variance) to Power of Reading made by each of the content areas is 47.55% by Vocabulary in Isolation, 17.38% by Geography, and 8.91% by Arithmetic Reasoning. By referring to Figure 2 one can see that

Vocabulary in Isolation can be further analyzed into

Direct variance to Power of Reading	33.72
Shared variance with Geography.....	9.69
Shared variance with Arith. Reasoning.....	4.14
Direct plus Shared Variance	47.55

Geography can be analyzed into

Direct variance to Power of Reading.....	6.32
Shared variance with Vocab. in Isolation.....	9.69
Shared variance with Arith. Reasoning.....	1.37
Direct plus Shared Variance	17.38

Arithmetic Reasoning can be broken down into

Direct variance to Power of Reading.....	3.40
Shared variance with Vocab. in Isolation.....	4.14
Shared variance with Geography.....	1.37
Direct plus Shared Variance	8.91
Total contribution to Power of Reading	73.84%

At the Level II analysis, with Vocabulary in Isolation as the subcriterion, English Literature, Grammar, and General Information account for 74.77% of Vocabulary in Isolation's variance. Now, with English Literature as the subcriterion, two subsystems, General Information and Geography, account for 57.13% of English Literature's variance. The other branches of the schema shown in Figure 2 can be read in a similar manner.

Summary of Substrata Analysis of Power of Reading

Power of Reading is a complex suprasystem dependent upon interrelationships of various subject-matter subsystems. Vocabulary in Isolation accounts for nearly half of the variance which creates individual differences in Power of Reading at the ninth-grade level. Geography and Arithmetic Reasoning, functioning either directly or indirectly, account for another 25% of the variance in Power of Reading. Not accounted for and probably intrinsic to Power of Reading or not measured in this study, is approximately 24% of the variance in Power of Reading. The remaining subject-matter subsystems are systems within systems, and the substrata analysis reveals the extent to which these subsystems interact with each other as well as the major criterion, Power of Reading.

Working System Hierarchy of Vocabulary in Isolation

The substrata analysis of Vocabulary in Isolation will provide information about the hierarchical organization of this suprasystem. Although Vocabulary in Isolation and Power of Reading correlate .8226 with each other, the major concern is with the substructural relationships underlying each of these complex subject-matter areas. While it is expected that there will be much overlap between Vocabulary in Isolation and Power of Reading, it is also anticipated that the substrata analysis will reveal constellations of subsystems which will show quantitative and qualitative differences in interaction among the various subsystems.

Level I: Substrata Analysis of Vocabulary in Isolation. The correlation matrix, Table 1, was submitted to the W-D-H Test Selection Method in order to determine the primary subsystems which underlie the ability to do well in a Vocabulary in Isolation test appropriate to the junior high school level.

Table 2, section A, presents the direct and shared variance among the subsystems selected to predict the criterion, Vocabulary in Isolation. When the beta weights are combined with the zero-order correlations, corrected for chance fluctuations according to the shrinkage formula and multiplied by 100, it is found that three subject-matter areas account for 80.77% of the variance of Vocabulary in Isolation and break down in the following manner:

(1) Power of Reading contributes 34.35%,

(2) English literature accounts for 26.45%, and

(3) Grammar explains 19.97% of the variance.

It is interesting to note that the variance which English Literature and Grammar share indirectly with Power of Reading is about equal to the direct association of these subsystems with Vocabulary in Isolation. It is reasonable to infer that proficiency in these subject-matter systems in itself is not sufficient basis for the attainment of high achievement in Vocabulary in Isolation; relationships among the subject-matter systems will enhance performance on Vocabulary in Isolation.

Level II: Substrata Analysis of Vocabulary in Isolation. Consistent with the statistical model of the substrata analysis, it is relevant to ask what subsystems of subject-matter variables underlie each of the predictors just reported for Power of Reading, English Literature, and Grammar?

To answer this question, a substrata analysis was made deleting Vocabulary in Isolation from the zero-order correlation matrix in Table 1 and allowing each of the predictors for Vocabulary in Isolation to become a subcriterion for a Level II-substrata analysis on all the remaining variables.

Table 2, Section B, presents the regression relationship of the various subject-matter subsystems selected to predict the subcriterion, Power of Reading. This portion of the table is read the same way as the previous analysis of Vocabulary in Isolation at Level I. Three content areas, English Literature, Arithmetic Reasoning, and Geography, account for Power of Reading. The three predictors directly indicate that a bit more than half of the variance is accounted for by Power of Reading. The remainder of the variance is distributed among the content areas.

The second subsystem predicting Vocabulary in Isolation is English Literature, which is now used as a subcriterion. General Information and Power of Reading account for 60.41% of the direct and shared variance of English Literature. Each of these subsystems accounts for about an equal amount of the variance, or 30.53% and 29.88%, respectively.

Table 2

Substrata Analysis of Vocabulary in Isolation--Subsystem in the Order Selected and the Accounted-for Portion of Variance Directly Associated With, and Shared Among, the Subsystems at Levels I, II, III (N = 120)

Criterion	Subsystem selected	Correl. w/crit.	Beta	Adj. Prop. Variance (as per cent) Direct to:				Shared from:
Section A								
Level 0	Level I			Voc.I	Power	Lit.	Gram.	Total
Voc. in Isol.	Pwr. of Rdg.	.8226	.42	17.54	0.00	10.03	6.78	34.35
	English Lit.	.7952	.33	11.13	10.03	0.00	5.29	26.45
	Grammar	.7129	.28	7.90	6.78	5.29	0.00	19.97
	Variance accounted for:			36.57	16.81	15.32	12.07	80.77
Section B								
From Vocabulary in Isolation at Level 0 to:								
Level I	Level II			Power	Lit.	A.Rsg	Geog.	Total
Pwr. of Rdg.	English Lit.	.7177	.40	15.90	0.00	3.20	9.31	28.41
	Arith. Rsng.	.4855	.26	6.65	3.20	0.00	2.58	12.43
	Geography	.6947	.34	11.43	9.31	2.58	0.00	23.32
	Variance accounted for:			33.98	12.51	5.78	11.89	64.16
Level I	Level II			Lit.	G.Inf	Power		Total
English Lit.	Gen'l Info.	.7201	.43	18.17	0.00	12.36		30.53
	Pwr. of Rdg.	.7177	.42	17.52	12.36	0.00		29.88
	Variance accounted for:			35.69	12.36	12.36		60.41
Level I	Level II			Gram.	G.Inf	Power		Total
Grammar	Gen'l Info.	.5869	.36	12.67	0.00	7.95		20.62
	Pwr. of Rdg.	.5765	.33	10.40	7.95	0.00		18.35
	Variance accounted for:			23.07	7.95	7.95		38.97
Section C								
From Vocab. in Isol. through Power of Reading at Level I to:								
Level II	Level III			Lit.	G.Inf.	Geog.		Total
English Lit.	Gen'l Info.	.7201	.46	21.06	0.00	11.78		32.84
	Geography	.6912	.36	12.69	11.78	0.00		24.47
	Variance accounted for:			33.75	11.78	11.78		57.31
Level II	Level III			A.Rsg	A.Fun			Total
Arith. Rsng.	Arith. Fund.	.5861	.59	33.80	0.00			33.80
	Variance accounted for:			33.80				33.80

(Table continued on next page)

Table 2 (Continued)

Criterion	Subsystem selected	Correl. w/crit.	Beta	Adj. Prop. Variance (as per cent) Direct to:			Shared from:	
Level II	Level III			Geog.	Hs-Cv	G.Inf.	Lit.	Total
	Hist.-Civics	.7693	.46	20.63	0.00	7.69	6.41	34.73
Geography	Gen'l Info.	.7205	.24	5.90	7.69	0.00	3.80	17.39
	English Lit.	.6912	.22	4.72	6.41	3.80	0.00	14.93
	Variance accounted for:			31.25	14.10	11.49	10.21	67.05
From Vocab. in Isol. through English Literature at Level I to:								
Level II	Level III			G.Inf.	Geog.	Power	Gram.	Total
	Geography	.7205	.42	17.15	0.00	8.00	4.45	29.60
Gen'l Info.	Pwr. of Rdg.	.6925	.28	7.74	8.00	0.00	3.37	19.11
	Grammar	.5869	.21	4.41	4.45	3.37	0.00	12.23
	Variance accounted for:			29.30	12.45	11.37	7.82	60.94
Level II	Level III			Power	Geog.	A.Rsg	G.Inf	Gram.	Total
	Geography	.6947	.35	12.24	0.00	2.49	6.05	3.29	24.07
	Arith. Rsng.	.4855	.24	5.77	2.49	0.00	2.06	1.24	11.56
Pwr. of Rdg.	Gen'l Info.	.6925	.24	5.76	6.05	2.06	0.00	2.59	16.46
	Grammar	.5765	.19	3.38	3.29	1.24	2.59	0.00	10.50
	Variance accounted for:			27.15	11.83	5.79	10.70	7.12	62.59
From Vocab. in Isol. through Grammar at Level I to:								
Level II	Level III			G.Inf.	Geog.	Lit.	Hs-Cv	Total
	Geography	.7205	.28	7.54	0.00	6.98	5.12	19.64
Gen'l Info.	English Lit.	.7201	.37	13.52	6.98	0.00	5.78	26.28
	Hist.-Civics	.6974	.24	5.87	5.12	5.78	0.00	16.77
	Variance accounted for:			26.93	12.10	12.76	10.90	62.69
Level II	Level III			Power	Lit.	A.Rsg	Geog.	Total
	English Lit.	.7177	.40	15.90	0.00	3.20	9.31	28.41
Pwr. of Rdg.	Arith. Rsng.	.4855	.26	6.65	3.20	0.00	2.58	12.43
	Geography	.6947	.34	11.43	9.31	2.58	0.00	23.32
	Variance accounted for:			33.98	12.51	5.78	11.89	64.16

The third-subject matter system which predicts Vocabulary in Isolation is Grammar. A substrata analysis of Grammar reveals that General Information and Power of Reading account for 38.97% of the direct and shared variance. Three fifths of the variance is accounted for by the two subsystems in direct association with Grammar. The remaining variance is shared between General Information and Vocabulary in Isolation. Most of the variance, 61.03%, remains to be accounted for.

Level III: Substrata Analysis of Vocabulary in Isolation. The substrata analysis is continued from Vocabulary in Isolation through Power of Reading at Level I to English Literature at Level II, which is now set as a subcriterion.

At Level III, two subsystems, General Information and Geography, precipitate to predict the variance in English Literature.

Table 2, Section C, shows that the two systems account for 57.31% of the total variance in English Literature. The direct and shared variance as well as the total variance is identical to that found for English Literature in a Level III substrata analysis when Power of Reading is the major criterion. This illustrates that each subsystem has an integrity of its own and yet bears a relationship within a larger suprasystem of knowledge.

Arithmetic Reasoning is the next subcriterion to be analyzed. As in the substrata analysis of Power of Reading, Arithmetic Fundamentals is the only system precipitated, accounting for 33.80% of the variance.

The third subcriterion is Geography. Although this subsystem is analyzed at Level III, the variables precipitated and the amount of variance accounted for are identical to those found for Geography at Level II, when Power of Reading was the major criterion.

All the predictors precipitated from the three subsystems, English Literature, Arithmetic Reasoning, and Geography, in the working system hierarchy of Vocabulary in Isolation account for an identical amount of the direct and shared variance. This parallels what was found when these subsystems were subcriteria in the substrata analysis of the working system of Power of Reading.

Figure 3 shows the interaction among the subject-matter subsystems and the suprasystem, Vocabulary in Isolation. However, because the substrata sequence in which the three subsystems are represented in the working system hierarchy of Power of Reading and Vocabulary in Isolation are different; the predictors precipitated in each of the three subsystems also make different contributions to their respective major criteria.

Table 3 presents the relevant parallel branches of the working-system hierarchies of Power of Reading and Vocabulary in Isolation in order to show the substrata sequences which provide a basis for prorating the variance accounted for in the major criterion from either Levels I, II, or III.

By using the sequential proration technique developed by Holmes (Holmes & Singer, 1961, 1965) the following is accomplished:

1. Each substrata factor's contribution to the variance in the working-system hierarchy of a given major criterion is determined regardless of the level at which it was precipitated.

2. Residuals are taken into account.

3. Particular predictors that were precipitated more than once at a given level can be accumulated, thus presenting a more concise picture of the working-system.

4. Comparisons can be made between other substrata factors precipitated in the various working system hierarchies of this study as well as other studies.

It is apparent that the second major purpose of this investigation has been substantiated, namely, that there are quantitative and qualitative differences among the subject-matter supra- and subsystems.

The reciprocal interaction that one system has on another may be inferred from an analysis of X on Y and Y on X regression equation. That reciprocity need not be symmetrical, as has been suggested by Holmes (1964a) and given theoretical neurological support by John (1962, p. 86). An indication of this non-symmetrical interaction

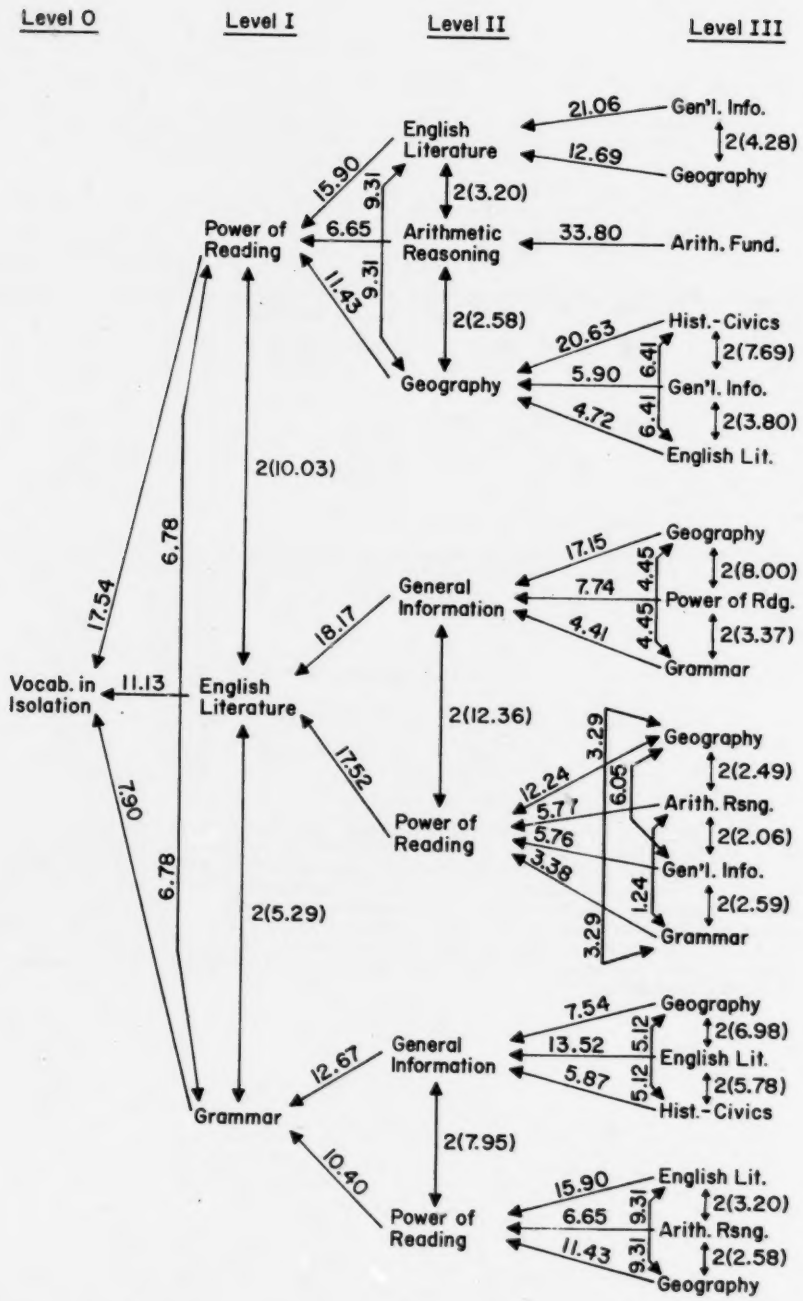

Fig. 3. Schema showing interaction among subject matter subsystems in the working system of Vocabulary in Isolation; figures represent adjusted proportional variance as per cent.

Table 3

Comparative Substrata Sequences and Prorated Distribution of Percentage of Criterion Variance in the Working Systems of Power of Reading and Vocabulary in Isolation

Sequences of substrata factors and their per cent contributions at each level of analysis							Prorated Dist. of percentage of criterion variance[a]
Level 0	Level I	%	Level II	%	Level III	%	
Power (See Fig. 2)	1. Voc.I	47.55	a. Lit.	35.94	1)G.Inf.	32.84	5.61
					2)Geog.	24.47	4.18
						57.31	9.79
	2. Geog.	17.38	a. Hs-Cv	34.73			
			b. G.Inf	17.39			6.04
			c. Lit.	14.93			3.02
				67.05			2.59
							11.65
	3. A.Rsg	8.91	a. A.Fun	33.80			3.01
Level 0	Level I	%	Level II	%	Level III	%	
Voc.I (See Fig. 3)	1. Power	34.35	a. Lit.	28.41	1) G.Inf	32.84	3.21
					2) Geog.	24.47	2.38
						57.31	5.59
			b. A.Rsg.	12.44	1) A.Fun	33.80	1.46
			c. Geog.	23.32	1) Hs-Cv	34.73	2.84
					2) G.Inf	17.39	1.41
					3) Lit.	14.93	1.21
						67.05	5.46

[a]The prorated distribution of percentage of criterion variance is calculated by multiplying together the contributions to variance at each successive level by analysis. For example, General Information contributes 32.84% to the variance of English Literature, which, in turn, contributes 35.94% to the variance in Vocabulary in Isolation, and Vocabulary in Isolation contributes 47.55% to the variance in Power of Reading. Thus, .3284 x .3594 x .4755 x 100 equals 5.61%, the contribution made by General Information through this substrata sequence, over and above that per cent of variance contributed through other substrata sequences.

is shown by using Power of Reading as the major criterion, or dependent variable, and Vocabulary in Isolation as the predictor, or independent variable, for an X on Y regression. The converse, or Y on X regression equation, is applied by using Vocabulary in Isolation as the major criterion, or dependent variable, and Power of Reading as the independent variable. This approach to non-symmetrical interaction is summarized in Table 4.

Table 4

Non-Symmetrical Reciprocal Interaction Between Power of Reading and Vocabulary in Isolation

Dependent variable	Independent variable	Correl. Dv vs. Iv	Adj. Prop. Variance Direct	Shared	Total
Power of Reading	Vocab. in Isolation	.8226	33.72	13.83	47.55
Vocab. in Isolation	Power of Reading	.8226	17.54	16.81	34.35

John (1962, pp. 86-87) attempts to explain reciprocal interaction in terms of a physiological model for simple conditioned responses as follows:

> While reciprocity of the interaction is suggested, this reciprocity need not be symmetrical, particularly when the associated discharges did not occur simultaneously in two particular foci. Assume that if a definite dominant focus is established in an area due to associated discharge of a group of neurons, afferent activity propagated into the region has an increased probability of achieving markedly nonrandom discharge from the focal area. The more recent the previous associated discharge which activated the focus, the higher the probability of subsequent nonrandom discharge which might be expected. Thus, activity propagating through a network from some region A, where associated discharge of an aggregate occurred earlier in time, might occasion markedly nonrandom discharge of some region B organized into a dominant focus by a more recent strong input from another origin. Conversely, the activity propagating through the network from the discharge of this strong focus B, established later in time than A will subsequently enter the region A. While some cells in region A may well be responsive to this input originating at B, discharge

in region A is likely to be more random than at B because more time has elapsed since the focus was established, excitability of neurons in the region is more likely to have deviated from the common state, and thus the strength of the group discharge tendency is lowered.

In terms of the far greater impact of Vocabulary in Isolation, 33.72% direct variance on Power of Reading in contrast to Power of Reading's impact on Vocabulary in Isolation to the extent of 17.14% direct variance, it appears that the strength of the neural aggregate discharge is not only a function of recency, but also of the following neurological and psychological reasoning adopted and extended from John (1962, p. 86).

1. Vocabulary is the sine qua non of reading comprehension. If there is no vocabulary, there can be no comprehension.

2. Although Vocabulary in Isolation is taught earlier than Power of Reading, its repeated association will increase the strength of neural aggregate discharge.

3. By repeated association Vocabulary in Isolation reaches a more "significant level of activiation" (John, 1962, p. 86) than Power of Reading.

4. The very high correlation between Vocabulary in Isolation and Power of Reading may also indicate

   a. a particular temporal pattern that has characterized the mode of discharge of the system and

   b. that various neural aggregates which have been associated during the establishment of a system constitute a set of reciprocally interlocked dominant foci.

   The foci and the relationships between them constitute a representation of the configuration of central excitations which have been so associated. Such a system of interrelated dominant foci will subsequently be referred to as a representational system (John, 1962, p. 86).

John's representational system is equivalent to Holmes' working system (1948). And John's neurologizing is consistent with Holmes' (1957) model of the workings of the brain during the reading process.

A representational system of the dominant foci in the working-system hierarchy of Vocabulary in Isolation is displayed in the schema shown in Figure 3. The schema is read in the same manner as Figure 2, which represents the working system of Power of Reading.

Summary of Substrata Analysis of Vocabulary in Isolation

A substrata analysis of Vocabulary in Isolation reveals a complex suprasystem undergirded by subsystems within subsystems of dominant foci at Levels I, II, and III. A comparison of the substrata sequences in the working systems of Power of Reading and Vocabulary in Isolation indicates that although the subsystems English Literature, Arithmetic Reasoning, and Geography have identical direct and shared variances within their respective subsystems, a sequential proration based upon the multiplier principle indicated that the three subsystems make different contributions to the variance of their major criterion.

The logic of the proration approach is given in terms of two basic postulates which assume that substrata factors are composed of systems within subsystems and, secondly, correlation reflects a mean, reciprocal interaction among two such subsystems.

Symmetrical and non-symmetrical interaction is further postulated with an analysis of X on Y and Y on X for Power of Reading and Vocabulary in Isolation. Non-symmetrical contributions to variance are found and explained by extending John's (1962) neurophysiological model and the author's psychological reasoning about the interaction of Power of Reading and Vocabulary in Isolation.

SUMMARY AND CONCLUSIONS

Basic Postulates of General Open Systems Theory and the Substrata-Factor Theory of Reading: Because the integrating construct of this study was General Open Systems Theory and the Substrata-Factor Theory, fundamental postulates common to the two theories were presented. Eight postulates were identified.

Postulate I: Exchange of energy, information, or matter with the environment through input and output channels

Postulate II: Maintenance of steady states

Postulate III: Self-regulating tendencies-re-establishment of steady states after being disturbed

Postulate IV: Equifinality

Postulate V: Dynamic interplay of the subsystems

Postulate VI: Feedback processes

Postulate VII: Progressive segregation and hierarchical order of subsystems

Postulate VIII: Progressive integration

Assumptions

Several fundamental assumptions had to be made in order to proceed with the substrata analyses:

1. Content areas examined in this study are complex suprasystems consisting of many diverse, yet functionally related and supportive, subsystems.

2. Substrata factors are dynamic sets of subsystems continually being organized and reorganized in the brain, depending on the task confronting the organism.

3. Hierarchies of subsystems upon which the substrata analysis is made depend on the concept of multi-causality or reciprocal causation.

4. While correlations cannot in any way substantiate reciprocal cause and effect relationships, the correlational analysis can and does give an estimate of the reciprocal interaction that may be going on among the variables.

5. Reciprocal interaction may be represented by an analysis of the X on Y and Y on X regression equation - for in educational psychology there is no such thing as an absolutely independent variable. Independent variables are reciprocally dependent and often statistically related.

6. The biological sciences, i.e., physiology, biochemistry, and neurology, can provide a framework for further understanding of the psychoeducational results of this study.

Conclusions

Generally, the theoretical and empirical aims of this study were achieved, i.e.,

1. There is an isomorphic relationship between all General Open Systems Theory postulates and Substrata-Factor Theory postulates. Therefore, in terms of the abstracted General Open Systems Theory postulates, the Substrata-Factor Theory exhibits internal consistency and external agreement with similar theories in other disciplines such as biology, chemistry, and physics.

2. Subject-matter areas can be conceived of as suprasystems girded by diverse, yet functionally related, subsystems.

More specifically,

1. Working-system hierarchies were found for each content area manifesting quantitative and qualitative differences in organization of substrata sequences, amount of variance accounted for, and redundancy of particular variables.

2. Reciprocal interaction can be inferred from an X on Y and Y on X regression analysis.

3. The proration sequential technique may provide a basis for determining the extent of a

particular subsystem's impact on the suprasystem.

Limitations

This study is a first approximation, and its generalities are limited to the basic assumptions, postulates, sampling, methods, and tests used. Further, theory building, testing, and logical analysis as well as knowledge of the nature of the brain is necessary to more fully understand the present findings as well as subsequent findings.

NOTES

[1]This paper is based in part upon a Ph.D. dissertation done by the writer at the University of California (Kling, 1965). The writer wishes to acknowledge the financial assistance of the Carnegie Corporation of New York.

[2]On a theoretical level Bertalanffy made pioneering inroads in the field of biology. See Bertalanffy, 1928, 1932.

[3]Personal communication, Holmes (1964b).

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